MODIS Cloud Products: A Brief Overview

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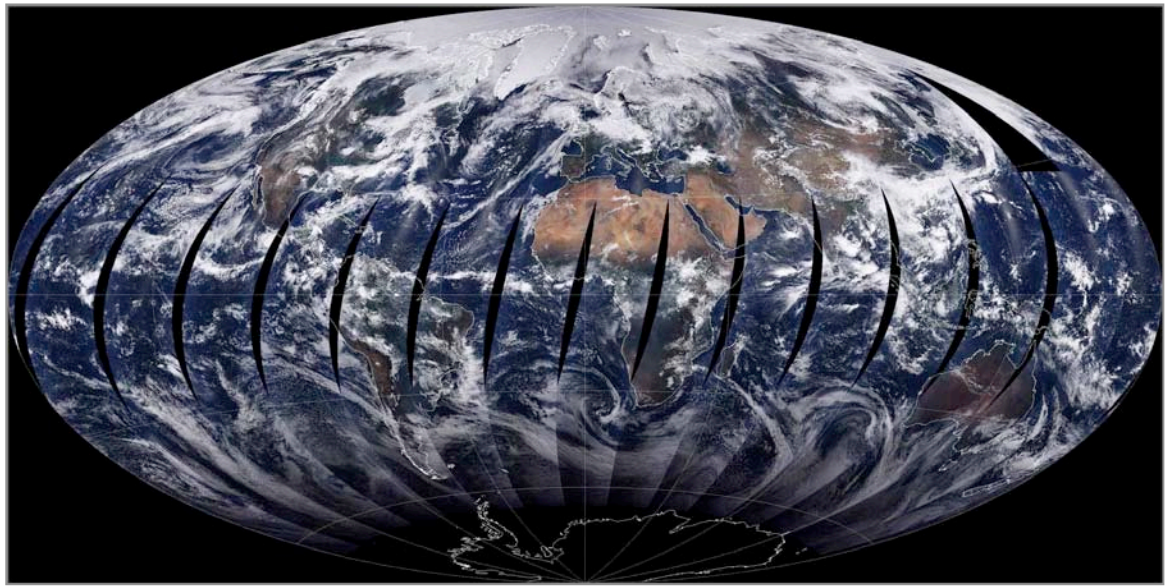
3rd AeroCom Workshop

GISS, NYC
1 December 2004



Topics

- MODIS Operational Cloud Products
  - Summary of Level-2 (pixel-level) and Level-3 (gridded) products
  - Cloud optical and microphysical products
- Algorithm issues: future enhancements, uncertainty analysis
- Issues for Modeling Comparisons
- Data availability and documentation
- Summary – agenda “questions”

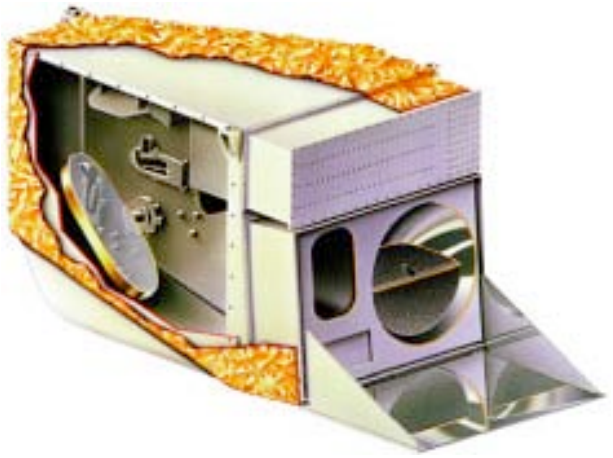
MODerate-resolution Imaging Spectroradiometer (MODIS)

Terra & Aqua NASA EOS Platforms

- launched 1999, 2002
- 705 km polar orbits, descending (1030L) & ascending (1330L)

Sensor Characteristics

- 36 spectral bands (0.41 to 14.385 μm), 4 focal plane arrays
- cross-track scanner, 2330 km swath width
- spatial resolution:
  - 250 m (bands 1 - 2)
  - 500 m (bands 3 - 7)
  - 1000 m (bands 8 - 36)
- onboard solar diffuser & solar diffuser stability monitor
- 2% reflectance calibration spec. accuracy



MODIS Cloud Products (Goddard DAAC)

Pixel-level products (Level 2)

- Cloud mask (**MOD35/MYD35**): *S. Ackerman et al., U. Wisconsin/CIMSS*

  1 km, 48 bits of information, 11 tests (20 spectral bands), overall clear-sky confidence reported in 1st 2 bits; also 250 m mask

- Cloud radiative and microphysical products (**MOD06/MYD06**)
  - Cloud top properties (pressure, temperature, effective emissivity): *P. Menzel et al., NOAA/NESDIS, CIMSS*

    5 km, CO_2 slicing for mid/upper clouds (p_c<600-700 mb), 11 μm for low clouds
  - Cloud optical, microphysical properties: *M. D. King, S. Platnick, et al., GSFC*
  - IR Thermodynamic Phase (5 km): *B. Baum, et al., NASA LaRC/CIMSS*
  - Thin cirrus reflectance: *B.-C. Gao, NRL*

- Joint Atmosphere product (**MODATML2/MYDATML**2): *King, Platnick, B. Wind*
  - Spatial subset of selected atmosphere products (clear sky, aerosol, clouds)
  - 5 km sample of selected cloud products

Gridded time-averaged products (Level 3):

Daily (**MOD08_D3/MYD08_D3**), 8-day (**MOD08_E3/MYD08_E3**), Monthly (**MOD08_M3/MYD08_M3**): *King, Platnick, Hubanks*

Cloud Optical & Microphysical Properties

Pixel-level (Level 2):

- Daytime observations at **1 km**
- Cloud optical thickness (τ), effective particle radius (r_e), **water path**, **retrieval thermodynamic phase** (≠ IR phase SDS, currently reported in 1 km *QA* SDS - will have its own SDS in collection 5)
- Algorithm applied globally (i.e., land, water, snow/ice surfaces) for liquid water and ice clouds
- Algorithm overview (current processing version is "collection 4", collection 5 will begin in early 2005)
  - Cloud reflectance look-up table method using single water non-absorbing band (0.65, 0.86, 1.2 μm) w/3 absorbing bands (1.6, 2.1, 3.7 μm) => **1 τ, 3 r_e (*2.1 μm derived r_e is primary*)**
  - Shorter-wavelength band choice depends on surface
  - Surface spectral albedo from MODIS ecosystem and albedo products
  - Cloud reflectance look-up table (plane-parallel homogeneous) calculated in the absence of an atmosphere and surface (incorporated dynamically)

Cloud Optical & Microphysical Properties

Gridded (Level 3):

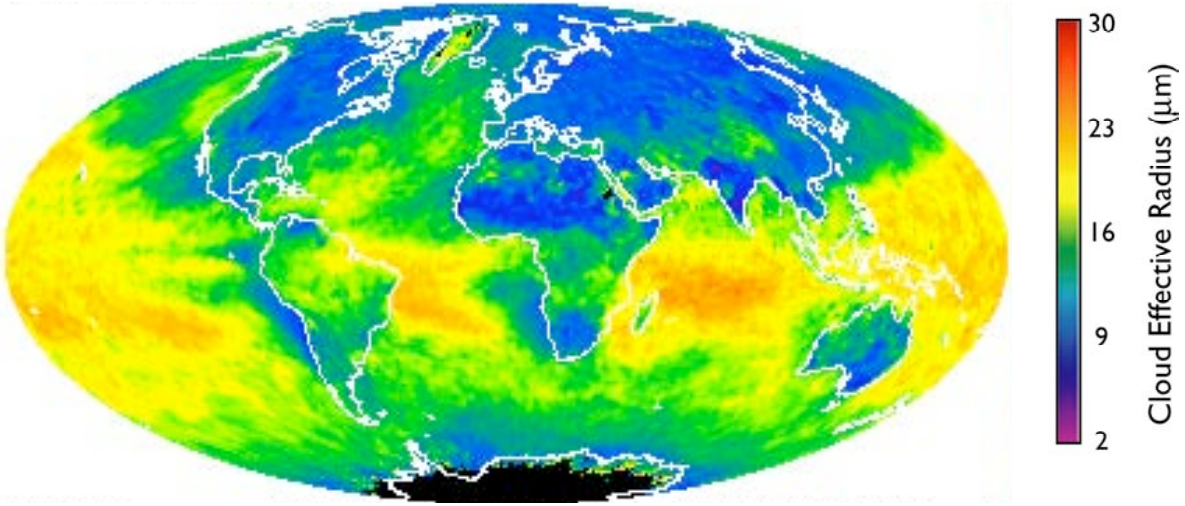
- Daily, 8-day, monthly aggregations of all atmosphere products on a **1° x 1° grid**
- File includes **statistics** (mean, standard deviation, linear & log for some parameters), and **marginal and joint probability histograms** for some cloud parameters.
  - Marginal
    water clouds: τ_c (45 bins), r_e (10), *LWP* (14)
    ice clouds: τ_c (30), r_e (12), *IWP* (15)
  - Joint
    τ_c-r_e, τ_c-T_c, r_e-T_c, τ_c-ε_e, r_e-ε_e
    water & *ice clouds*: τ_c (11 bins), r_e (10 bins), T_c (12 bins), ε_e(9 bins)

Collection 5: adding joint histograms vs. p_c, including ISCCP-like τ_c-p_c

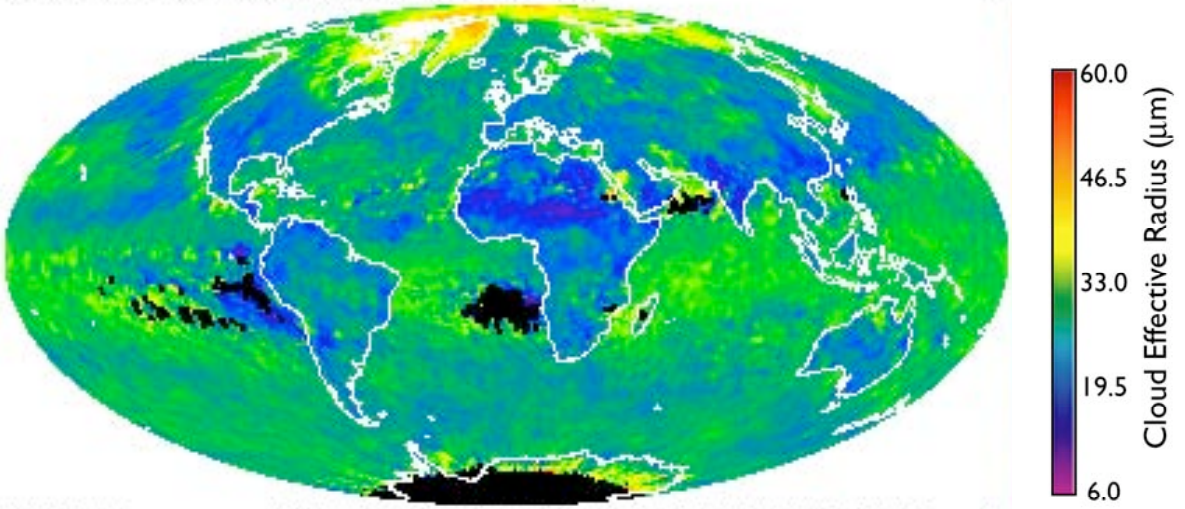
- **QA-weighted statistics** for τ_c, r_e implemented in current collection 4 processing, water path QA to be implement in collection 5
- Mapped subset of L3 statistics available directly from MODIS atmosphere web site

Monthly Mean Cloud Effective Radius (QA weighting)

Terra April 2003 (collection 4)



liquid water clouds

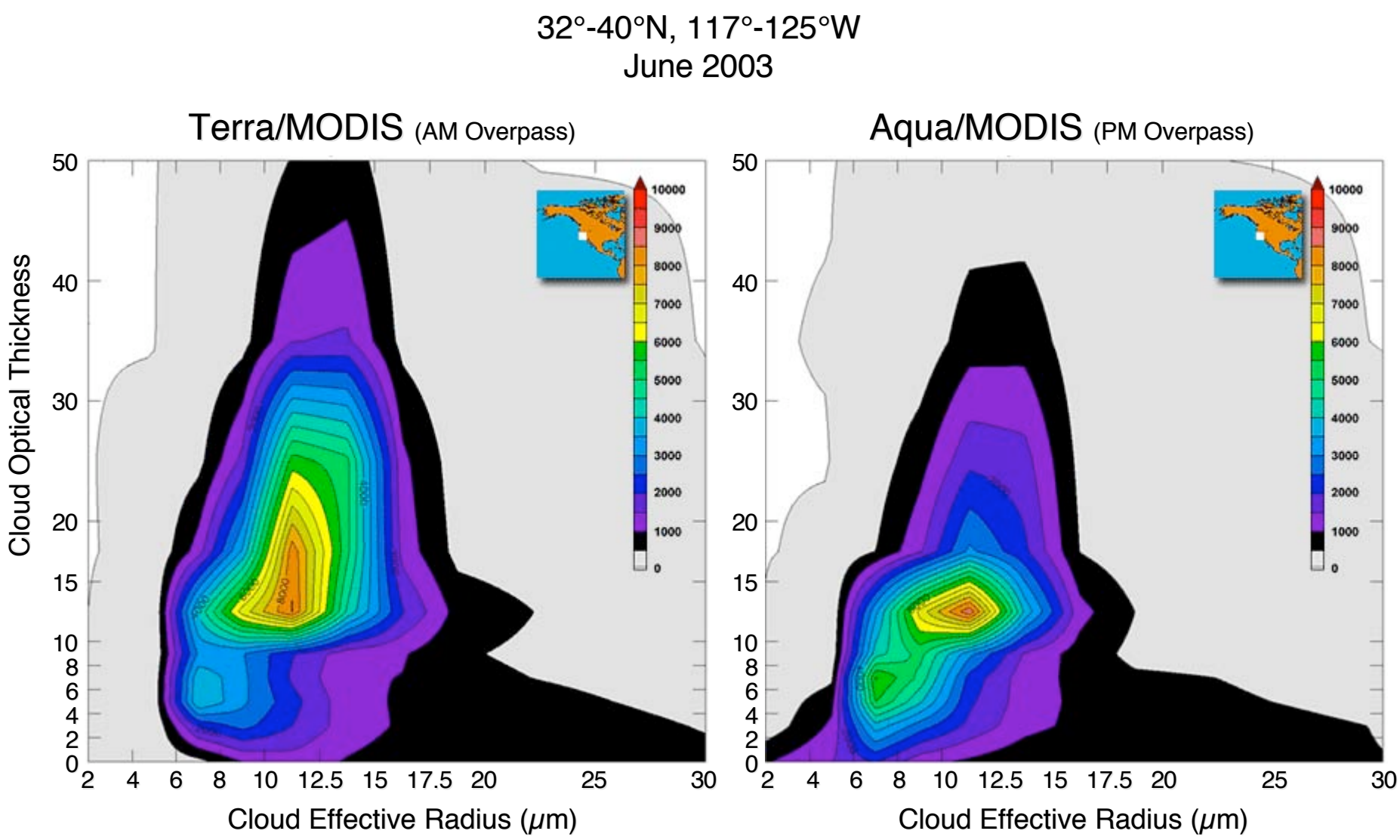


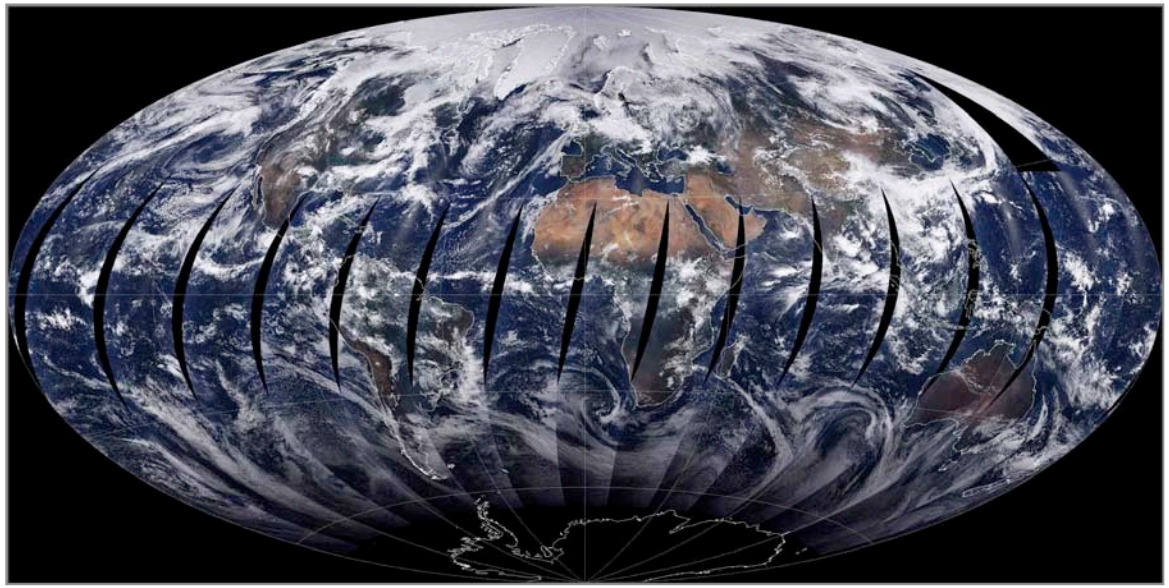
ice clouds

S. Platnick, AeroCom, 1 Dec 2004

California/California Current Stratocumulus Regime

Monthly Joint Histogram Counts of Liquid Water Clouds over Ocean





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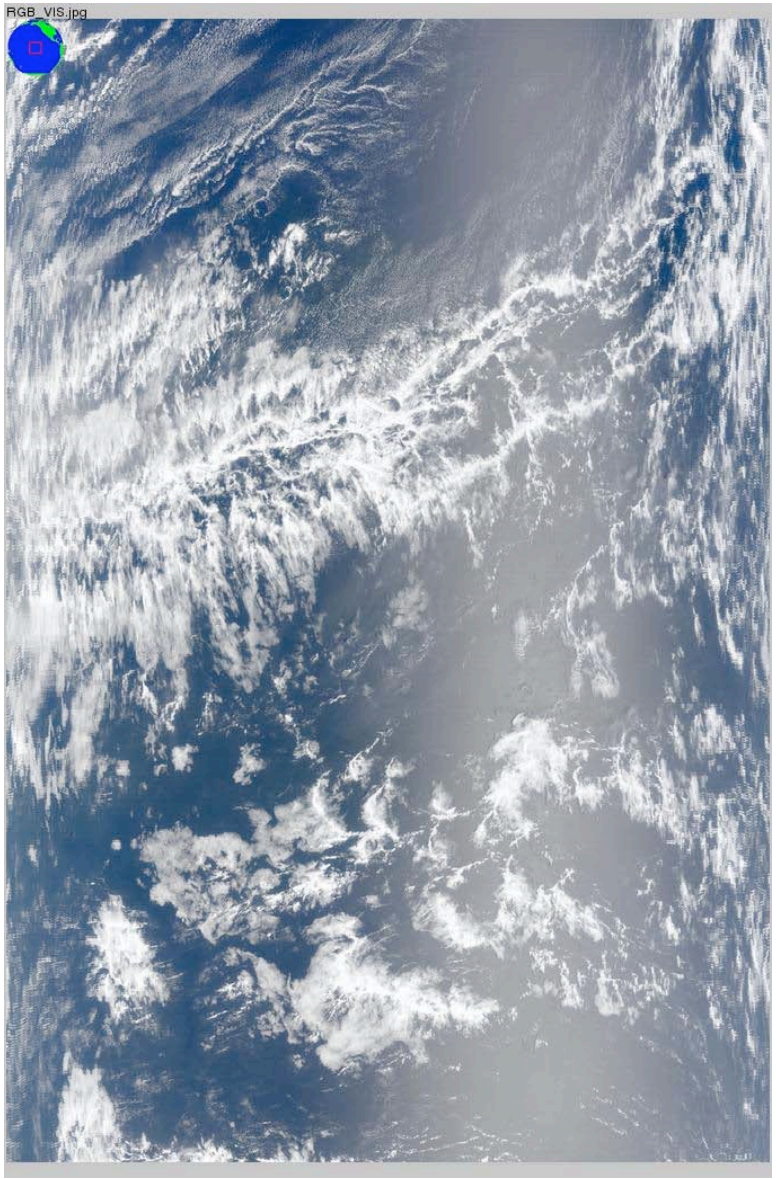
MODIS Cloud Optical/Microphysical Retrieval Concerns

Issues addressed in upcoming "collection 5" processing stream:

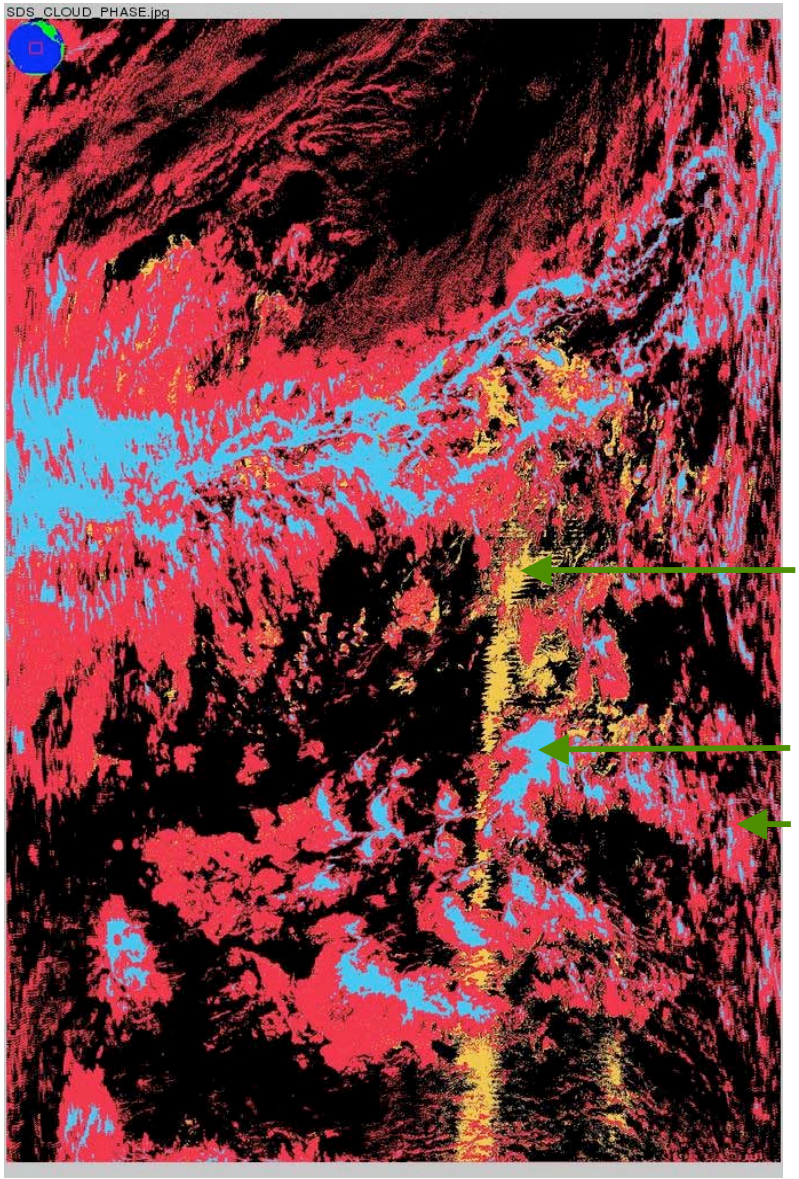
- False clouds (e.g., sun glint, heavy aerosol, …)
  - New collection 5 module: logic includes spatial variance + standard phase retrieval + 1.38 μm + spectral tests
- Sub-pixel cloud fraction
  - Collection 5: cloud "edge" pixels not processed, investigating use of 250 m cloud mask
- Multilayer/phase cloud scenes
  - Collection 5 has a new SDS to flag likely multilayer/phase pixels
- Snow/ice & land surfaces
  - Implementation of 1.6-2.1 μm band combination retrieval for snow/ice surfaces, new high resolution land surface spectral albedo map
- Numerical uncertainties
  - Pixel-level uncertainty analysis SDS in collection 5

Sunglint Example - Equatorial Pacific

RGB (true color)



Retrieval processing result



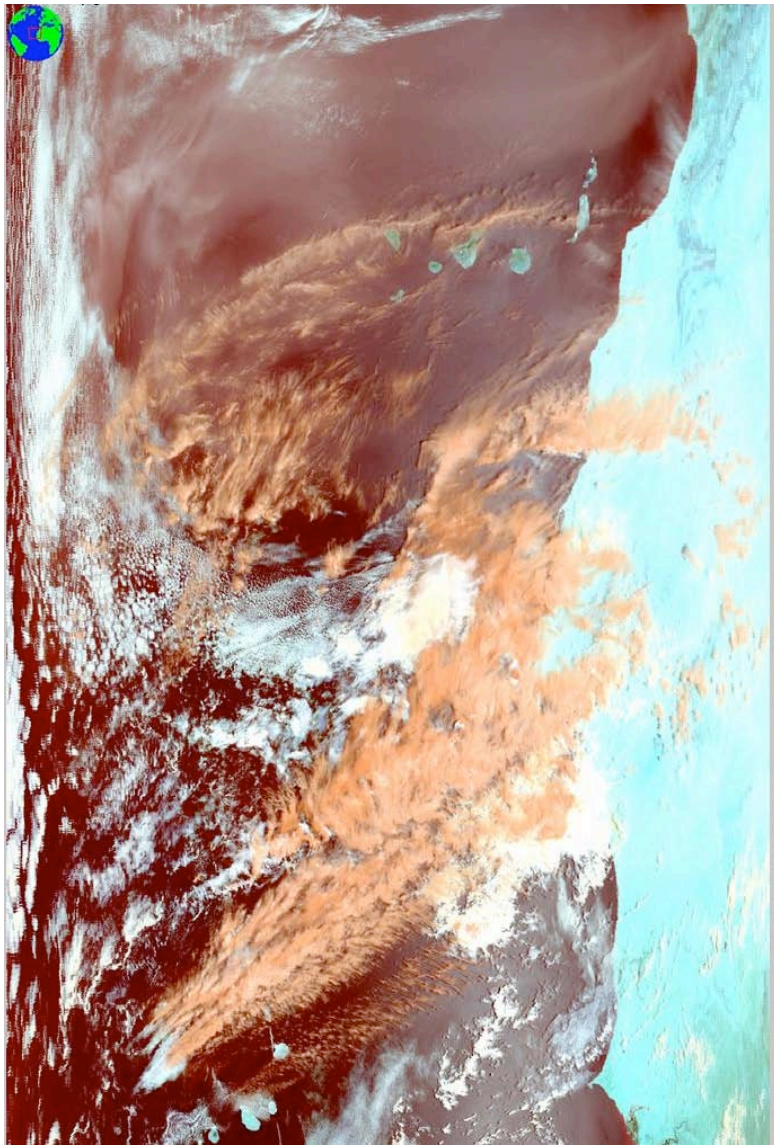
flagged by mask, restored to "clear"

ice cloud

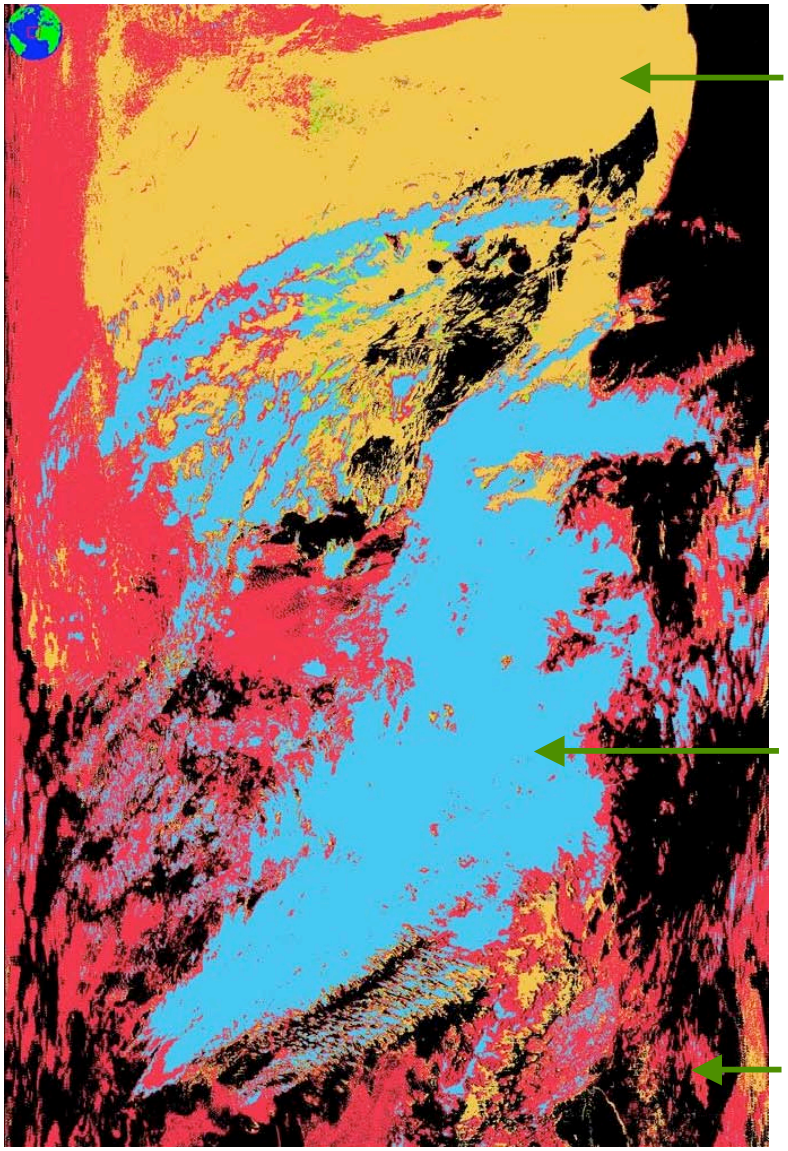
water cloud

Saharan Dust Example

RGB (SWIR)



Retrieval processing result



flagged by mask, restored to "clear"

ice cloud

water cloud

Pixel-level Uncertainty Analysis for Collection 5

S. Platnick, B. Wind

Currently incorporating the effect of the following sources on inferred cloud-top reflectance:

1. Instrument calibration
2. Atmospheric correction uncertainty
3. Spectral surface albedo uncertainty

Details:

- Uses sensitivity derivatives calculated from reflectance libraries, e.g.:

$$\left.\frac{\partial \tau}{\partial R_1}\right|_{R_2} = f\left(\left.\frac{\partial R_1}{\partial \tau}\right|_{r_e}, \left.\frac{\partial R_1}{\partial r_e}\right|_{\tau}, \left.\frac{\partial R_2}{\partial \tau}\right|_{r_e}, \left.\frac{\partial R_2}{\partial r_e}\right|_{\tau}\right)$$

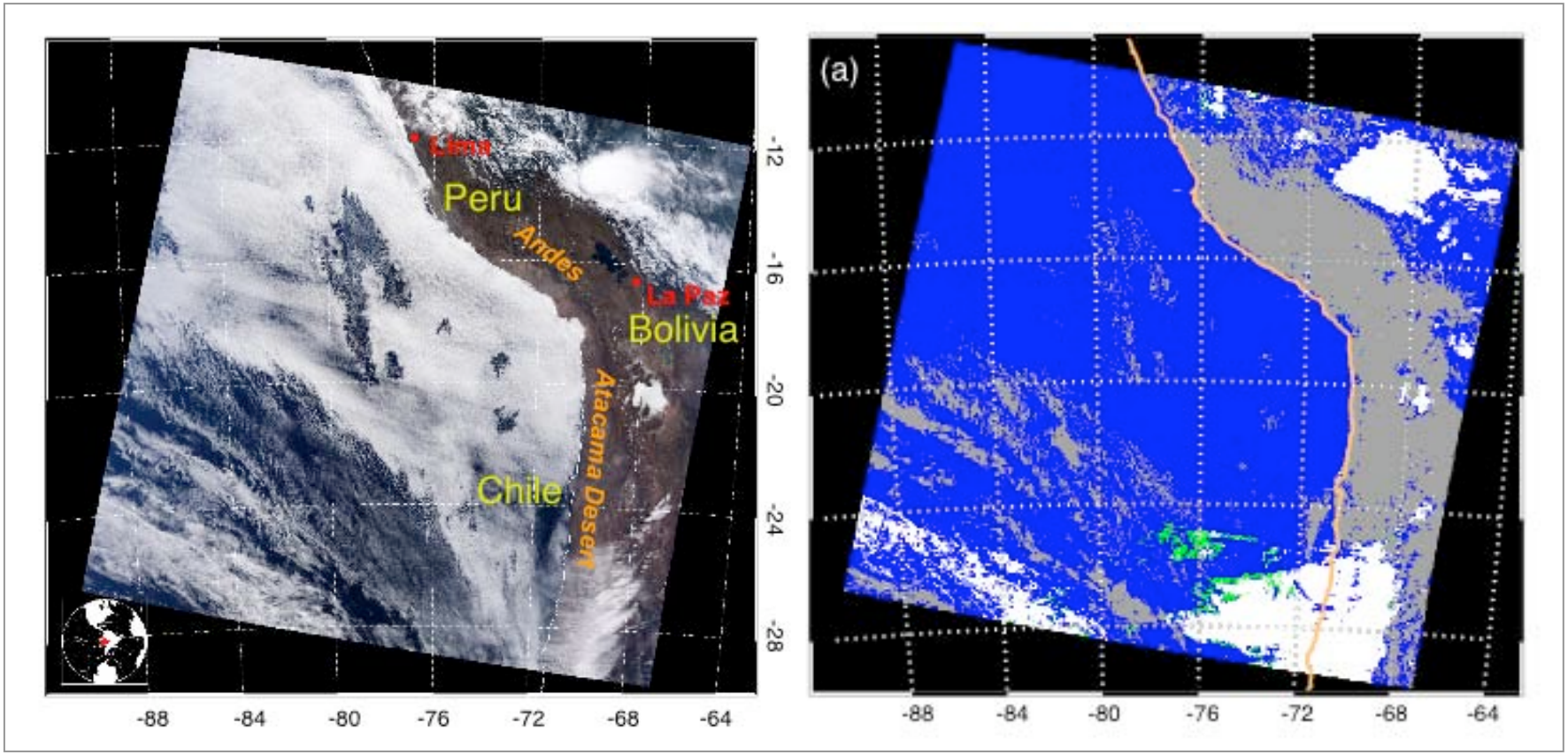
- Represents a likely minimum uncertainty, i.e., missing components (**ice cloud models**, **vertical cloud structure** including multi-layer clouds, …)

- Random L2 uncertainties may be reduced/eliminated during L3 aggregations

Granule-level Retrieval Example - Collection 4 Stream

Terra granule, coastal Chile/Peru, 18 July 2001, 1530 UTC

[Platnick et al., *IEEE Trans. Geosci. Remote Sens.*, **41**]

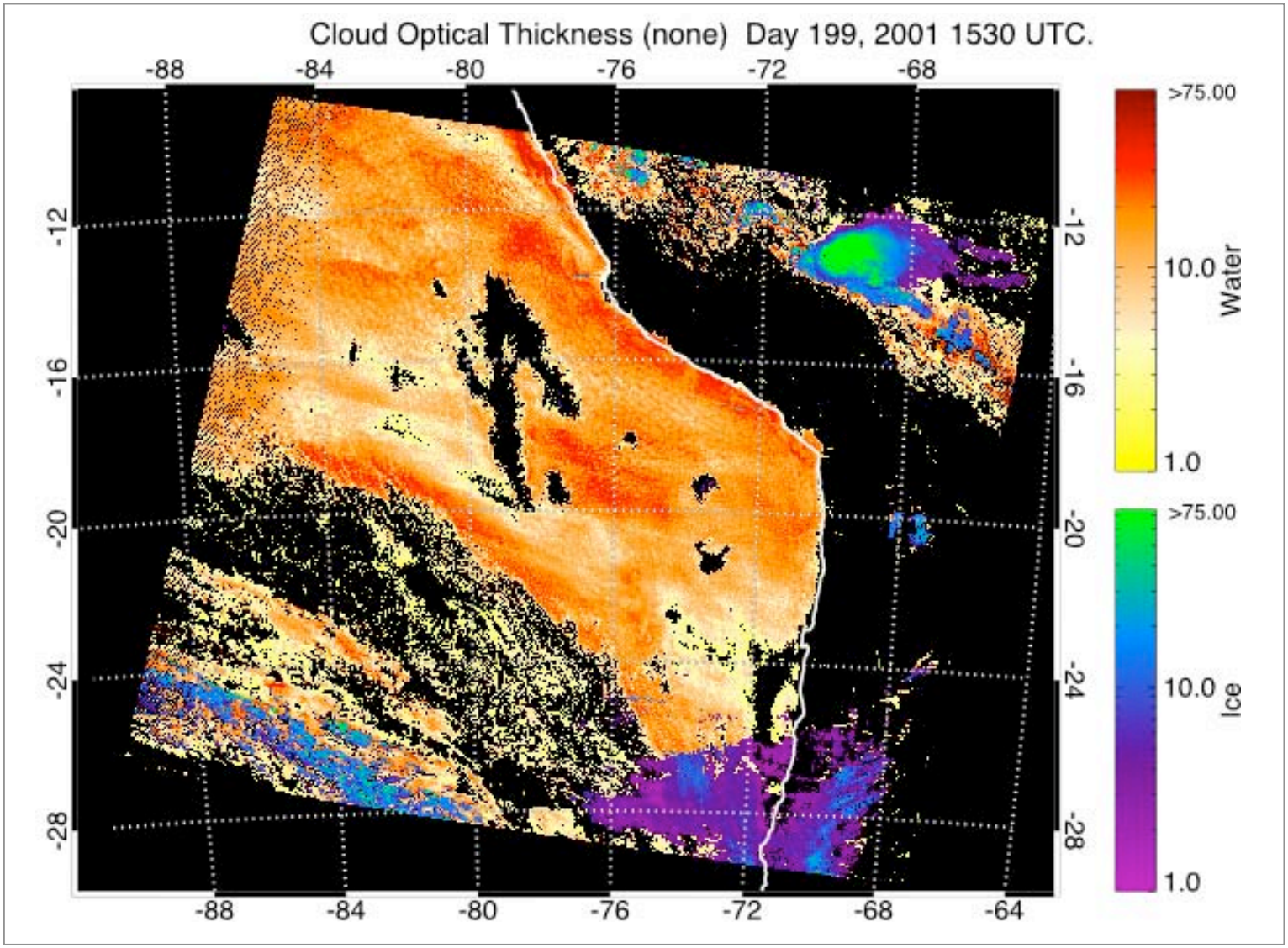


RGB true-color composite

phase retrieval

uncertain ice liquid water no retrieval

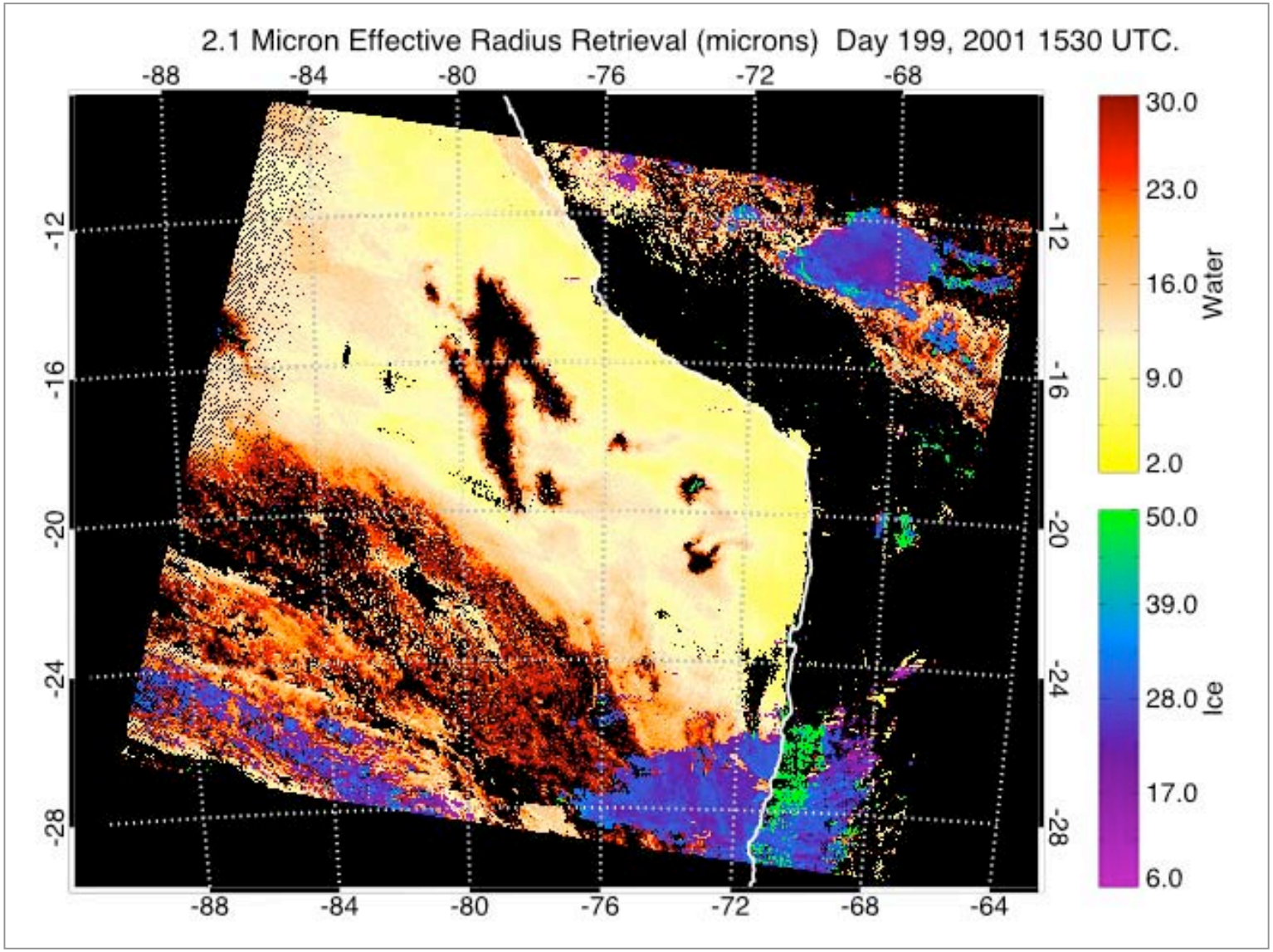
Optical Thickness



S. Platnick, AeroCom, 1 Dec 2004

Effective Radius (μm)

(particle size derived with 2.1 μm band)



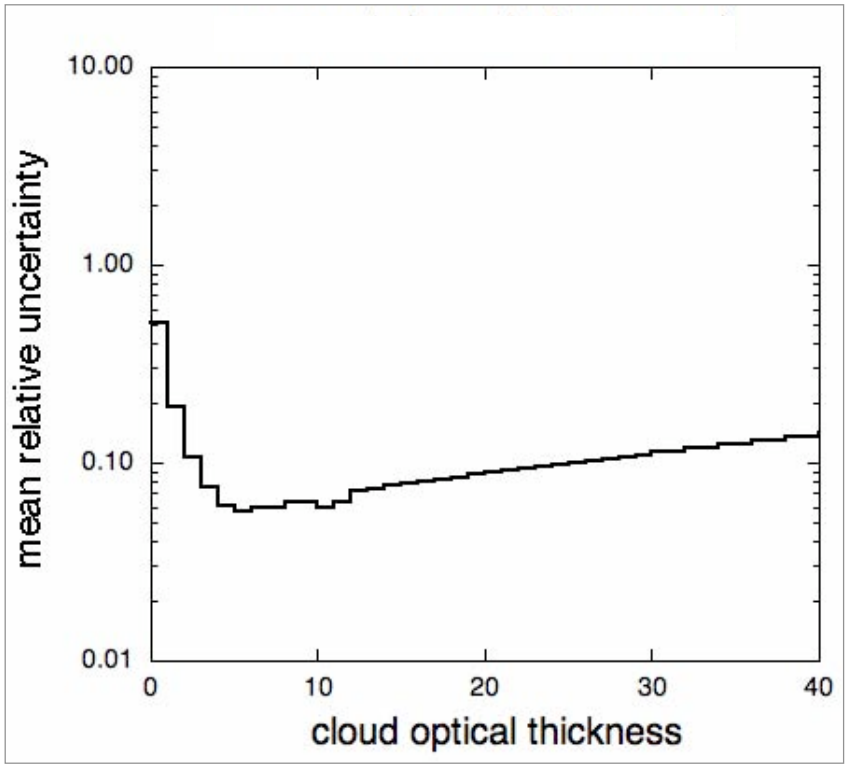
S. Platnick, AeroCom, 1 Dec 2004

Pixel-level Uncertainty Analysis

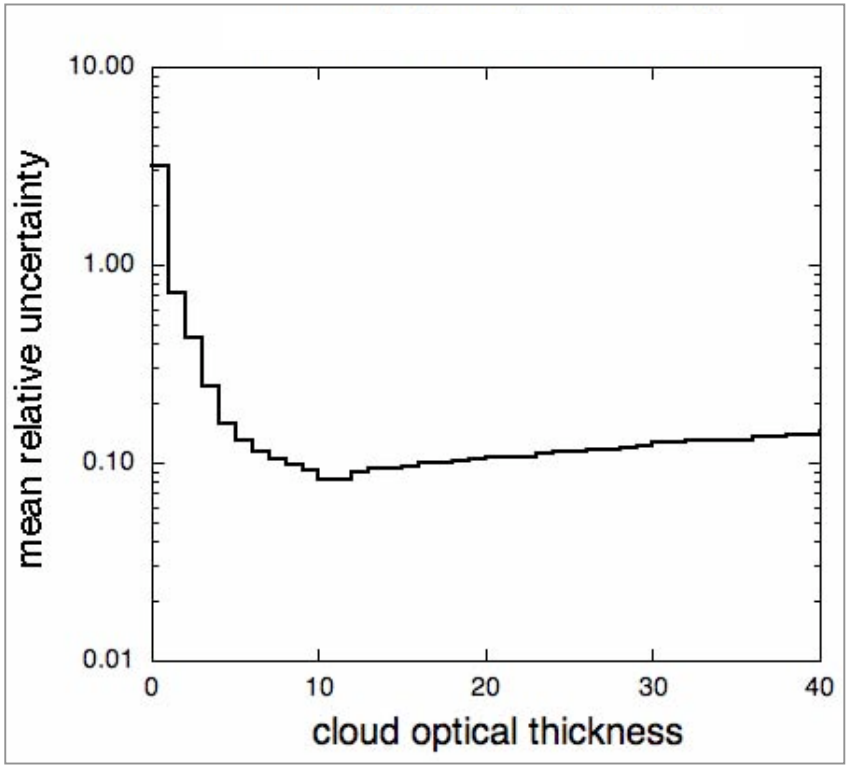
Peru granule (18 July 2001)

τ : liquid water clouds

water clouds over ocean



water clouds over land

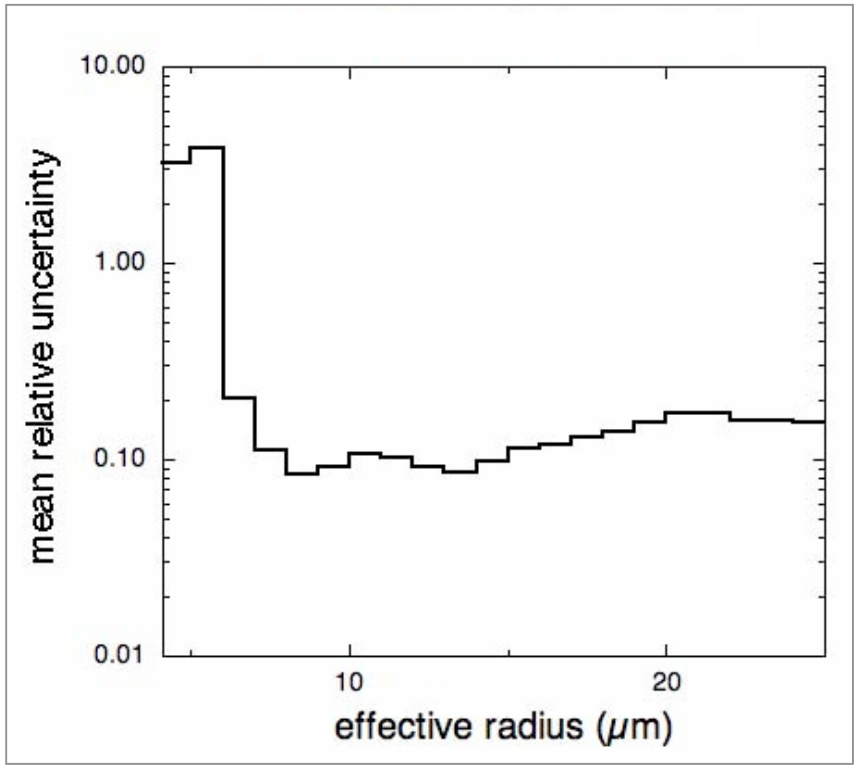


Pixel-level Uncertainty Analysis

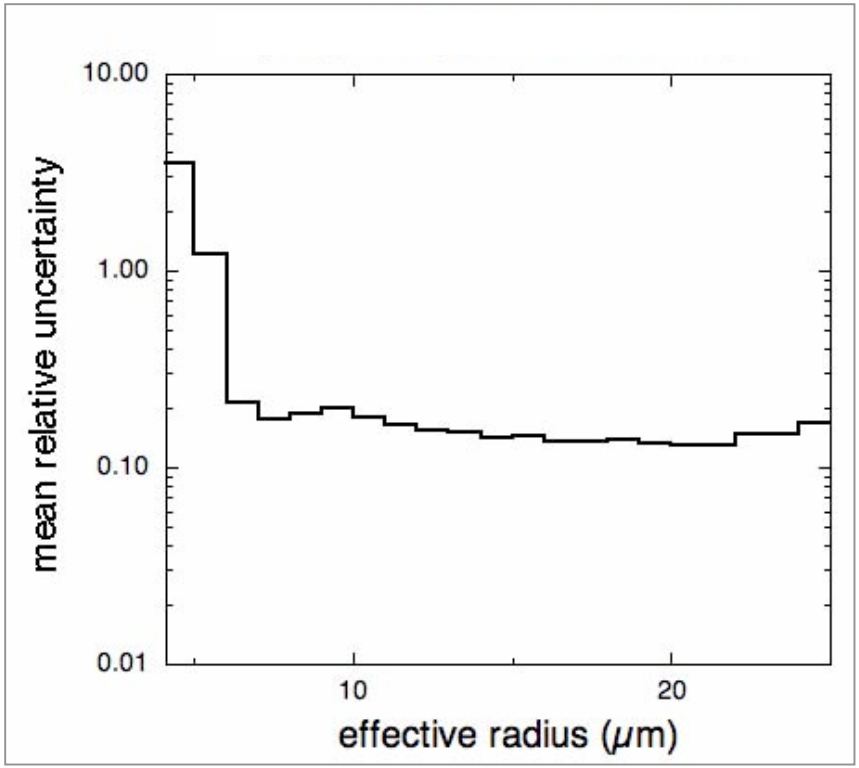
Peru granule (18 July 2001)

r_e: liquid water clouds

water clouds over ocean



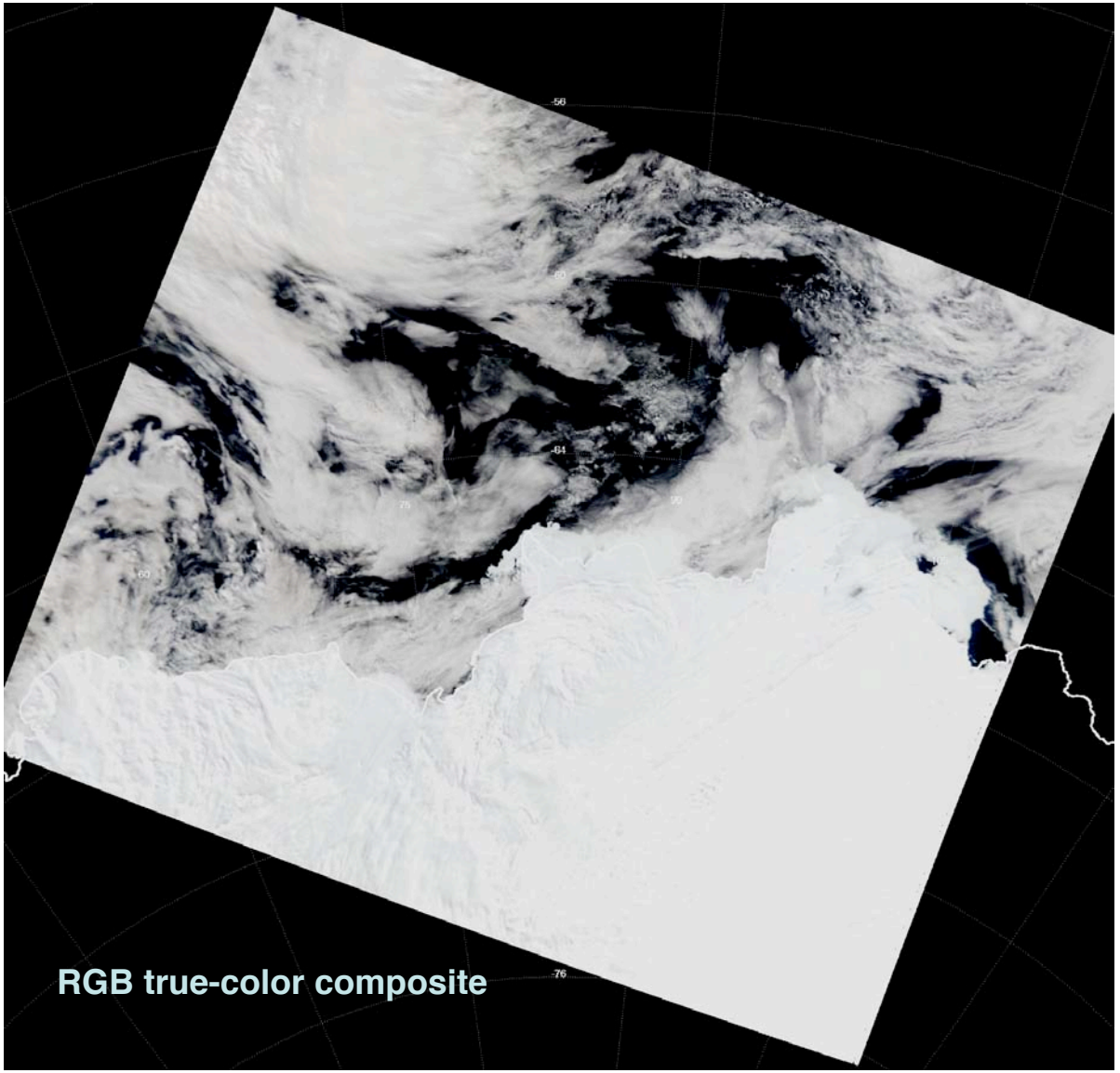
water clouds over land



Retrieval Example - Collection 5

Terra granule, coastal Antarctica, 12 Feb 2001, 0350 UTC

[1st science test, partial implementation of collect 5 algorithm]



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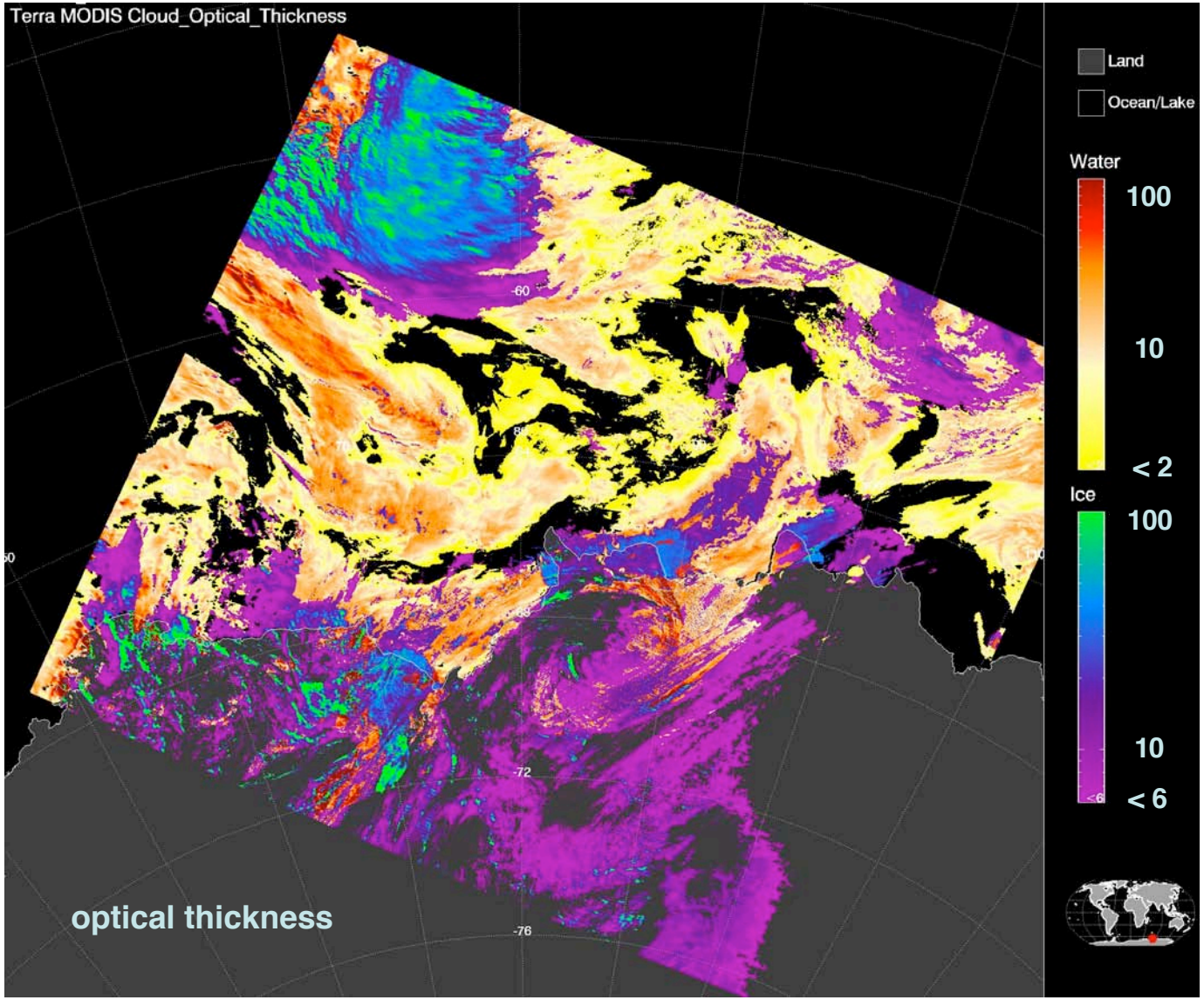

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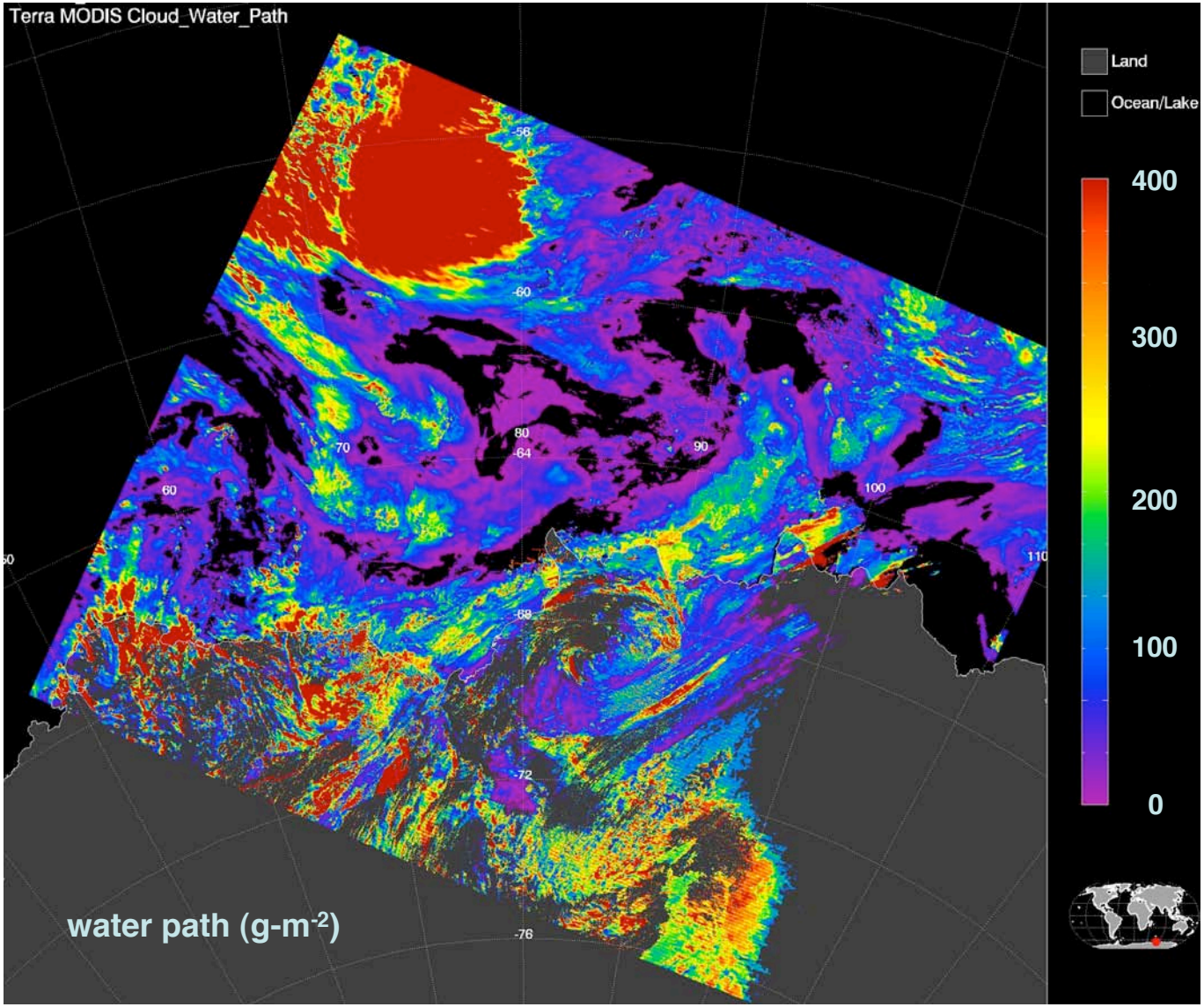

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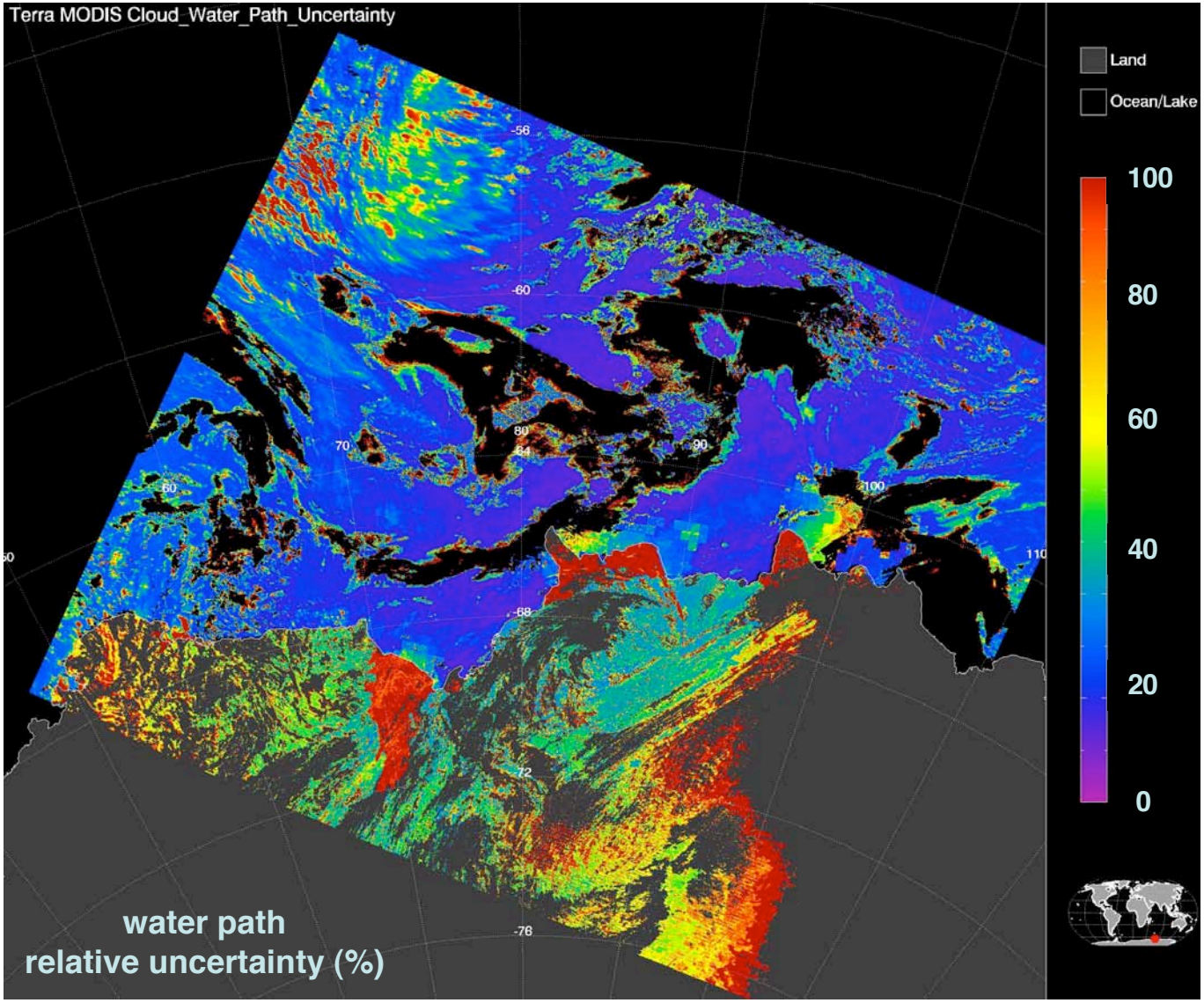

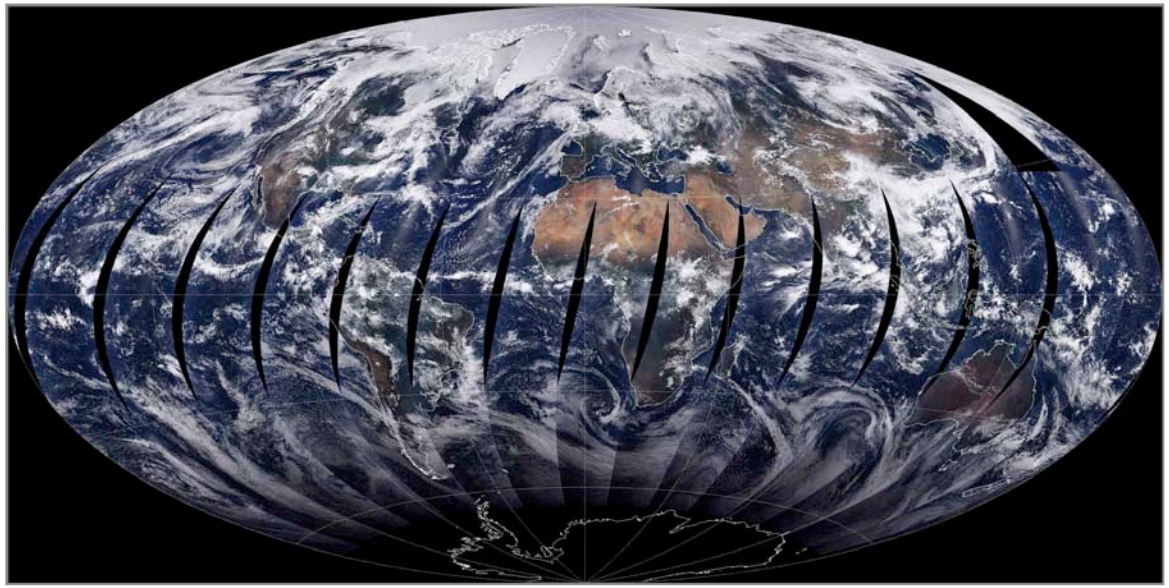

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Model Validation

MODIS Cloud "Simulator"

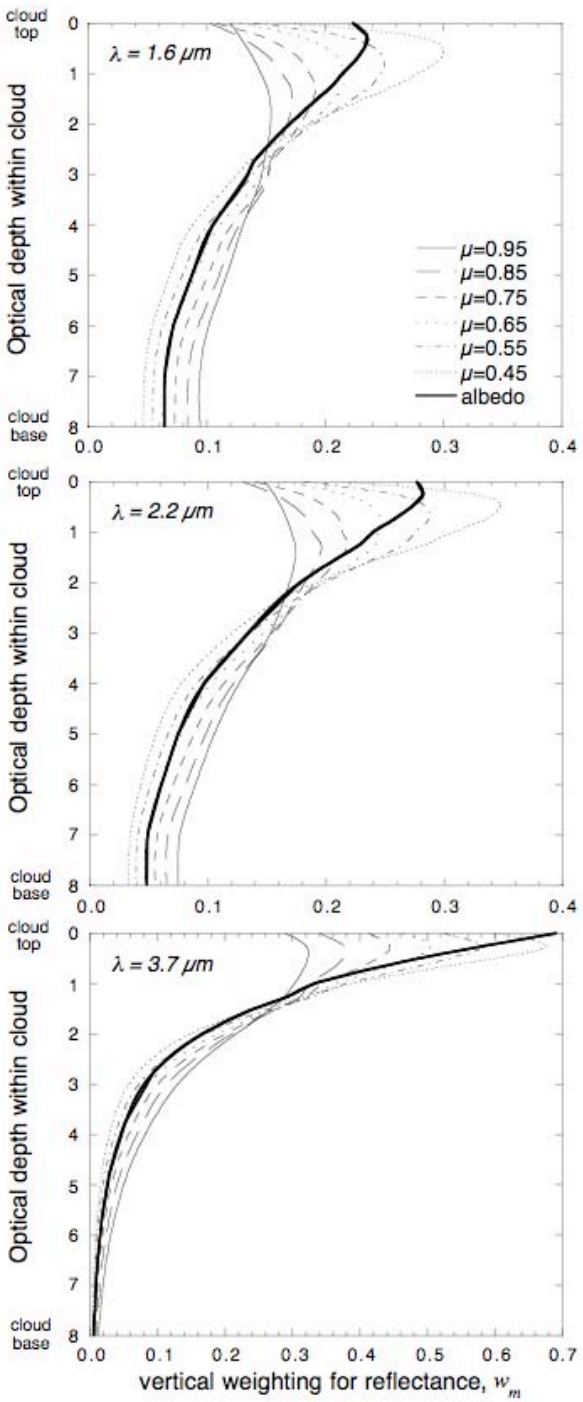
Simulate MODIS-like retrievals of cloud fraction, phase, τ, r_e, water path, p_c, T_c from model cloud generator. As with ISCCP simulator, but …

- **Cloud fraction**: need to simulate cloud mask spectral tests (approximation: use threshold τ)
- **Phase**: straightforward for single phase column; otherwise, MODIS "retrieval phase" uses solar + IR bands + cloud mask tests (approx.: use τ_{ice} threshold)
- τ: straightforward
- ***r*$_e$**: 2.1 μm effective vertical weighting depends on geometry, cloud microphysical profile, (rough approximation: assign effective τ depth; better: estimate weighting function)
- **Water path** = $\rho_{l,i}$ 2/3 τ r_e
- ***p*$_c$**: <700 mb, need approximation for CO_2 weighting functions (can likely start with threshold-dependent estimates); >700 mb, as w/ISCCP simulator with unity emissivity

Vertical Effects

example approximate reflectance weighting functions vs. view angle, τ_c=8

retrieved $r_e \approx \int_0^{\tau_c} r_e(\tau)\, w_m(\tau, \tau_c)\, d\tau$



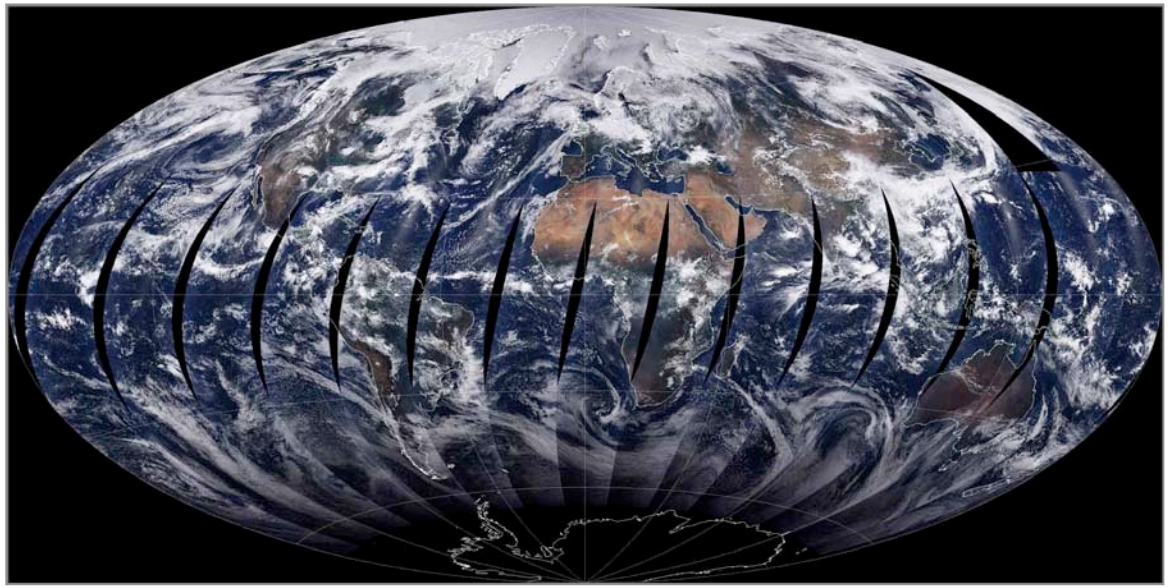
Platnick, JGR, 2001

Example τ depth corresponding to retrieved r_e

τ_c=8, μ_0=0.65, μ variable, dark ocean surface, adiabatic cloud

Table 4. Weighting-derived effective radius retrievals versus spectral band and cosine of the viewing zenith angle, μ. Calculated for $\tau_c = 8$, effective radii varying from r_{base}= 5µm to r_{top}= 12µm with an adiabatic profile, $\mu_0 = 0.65$, and a black surface.

Viewing zenith angle μ	1.6 µm			2.2 µm			3.7 µm		
	r_e^* w_m estimate (µm)	τ corresponding to r_e^*	1- z/h corresponding to r_e^*	r_e^* w_m estimate (µm)	τ corresponding to r_e^*	1- z/h corresponding to r_e^*	r_e^* w_m estimate (µm)	τ corresponding to r_e^*	1- z/h corresponding to r_e^*
0.95	10.4	4.2	0.38	10.6	3.8	0.34	11.3	2.2	0.19
0.85	10.5	4.0	0.36	10.6	3.7	0.33	11.4	1.9	0.16
0.75	10.6	3.8	0.34	10.8	3.4	0.30	11.5	1.7	0.14
0.65	10.7	3.5	0.32	10.9	3.1	0.28	11.5	1.5	0.12
0.55	10.8	3.3	0.29	11.0	2.9	0.25	11.6	1.3	0.10
0.45	11.0	3.0	0.26	11.1	2.5	0.22	11.7	1.1	0.09



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Data Availability and Documentation (Terra & Aqua)

- MODIS atmosphere products (descriptions, Level-1b and Level-3 browse imagery, documentation, contact information, tools, data ordering info, etc.) at: ***modis-atmos.gsfc.nasa.gov***
  - MODIS surface albedo, ecosystem, and NDVI filled-in global data sets
  - Image Production for Web site (228 MB of images produced every day)
  - Link to MODIS online visualization and analysis system (MOVAS)

- Data archived at Goddard DAAC

  MODIS Multiple Data Ordering Page (ordering interface for level-1b, geolocation, atmosphere, and ocean data):

  http://daac.gsfc.nasa.gov/daac-bin/MODIS/Data_order.pl?PRINT=1

- Collection 4 reprocessing complete for Aqua

  Terra and Aqua forward stream near real-time

- Collection 5 enhancements and reprocessing to begin for Terra

  Atmosphere team ~ February 1, 2005 (reprocessing)
  Land team ~ July 1, 2005 (and atmosphere forward processing)

modis-atmos.gsfc.nasa.gov

MODIS Atmosphere

HOME | PRODUCTS | IMAGES | VALIDATION | NEWS | STAFF | FORUM | REFERENCE | TOOLS | HELP

AEROSOL | H2O VAPOR | CLOUD | PROFILE | CLD. MASK | JOINT | (Level-2 Products)

DAILY | EIGHT DAY | MONTHLY | (Level-3 Products) | ALBEDO | NDVI | ECOSYSTEM | (Level-3 Ancillary)

HOME

INTRODUCTION

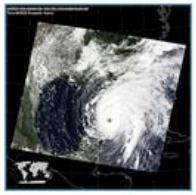
You have accessed a U.S. Government Computer System. Visitors are authorized to use this system to acquire MODIS-Atmosphere related data information, images, products, and services only. Access to this system constitutes visitors consent to keystroke monitoring. Any malicious action or intent on this system is prohibited and punishable under Federal Law.

Introduction

Overview

One of the most important ecological issues concerning our planet is climate change. It is generally agreed that the Earth's climate will modify in response to radiative forcing induced by changes in atmospheric trace gases, cloud cover, cloud type, solar radiation, and tropospheric aerosols (liquid or solid particles suspended in the air). In order to develop conceptual and predictive global climate models, it is vital to monitor these properties. Two MODIS (Moderate Resolution Imaging Spectroradiometer) instruments, the first launched on 18 December 1999 onboard the Terra Platform and the second on 4 May 2002 onboard the Aqua platform, are uniquely designed (wide spectral range, high spatial resolution, and near daily global coverage) to observe and monitor these and other Earth changes. (MORE)

Feature L1B Granule Image



Ivan: A Powerful Catagory 5 Hurricane
On September 13th 2004, the Terra-MODIS instrument captured this image of extremely dangerous Hurricane Ivan in the eastern Gulf of Mexico moving steadily towards the U.S. In this image, the center of Ivan (a Category 5 hurricane on the Saffir-Simpson scale) was located about 100 miles northwest of the western tip of Cuba. Hurricane Ivan packed maximum sustained winds near 160 mph (260 kph) with gusts to 195 mph at its peak intensity, as it devastated parts of the Carribean. Ivan dropped to a Category 3 by the time it made landfall early Thursday, September 16th, near Gulf Shores, Alabama; but still cut a path of destruction across the South and Northeast U.S. that left more than 45 people dead, 16 of them in Florida. Image by Ridgway, Gray, & Hubanks, NASA

Spotlight

MODIS Data Processing Schedule and Calendar - All MODIS data (both Terra and Aqua platforms) are now available in Collection 004. This means that over four years of continous validated Atmosphere products from Terra/MODIS, and over two years of continous validated Atmosphere products from Aqua/MODIS, both processed with the latest updated (version 4) program executables (PGE's) are available. [MORE]

Introducing the MODIS Online Visualization and Analysis System (MOVAS) - This new and powerful web-based MODIS data analysis tool is designed for visualization and analysis of the Terra / MODIS Level-3 Atmosphere Monthly global product (MOD08_M3). Users can plot area average (area plot) and time series (time plot) or generate ASCII output for selected area and time period. Spatial coverage is 90°S - 90°N, spatial resolution is 1° x 1°, and temporal resolution is monthly. [MORE]

Introducing the MODIS Multiple Data Ordering Page (MDOP) - This new and user-friendly MODIS data ordering system gives the user convenient means to simultaneously order several MODIS Data Sets, including Geolocation. This system also works well for single products. It should be noted that this is a vast improvement over previous ordering interfaces. [TERRA] [AQUA]

Introducing the new L2 Joint Atmosphere Product - A compact L2 product containing the "greatest hits" of MODIS-Atmosphere science parameters began production on October 14th 2003. The first available data days are julian days 285 (10/12/03) for Aqua and 286 (10/13/03) for Terra. [MORE]

Near Real-time MODIS L1B Images - View near-real time RGB mapped images of all daytime MODIS granules from either the Terra (February 2000 to current) or Aqua (June 2002 to current) platforms. [TERRA] [AQUA]

Near Real-time Monthly Global Images - View monthly global images of the full set of L3 MODIS Atmosphere products from either the Terra (March 2000 to current) or Aqua (July 2002 to current) platforms. [TERRA] [AQUA]

Summary

Agenda Questions

- What cloud products are available?

  L2 cloud-top properties: p_c, T_c, ε_c (5 km)

  L2 optical, microphysical: τ, r_e, *WP*, phase (1 km)

  Level-3 aggregations

- How accurate vs. regional, seasonal, cloud type?

  Fixed numbers not possible/misleading, need pixel-level uncertainty calculations

- Quasi-simultaneous aerosol data available?

  YES

- How representative is r_e vs. mean cloud property (vertical)?

  Fixed numbers not possible/misleading, discussed